Total Activation Change of Visual and Motor Area due to Various Disturbances

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Abstract
Brain activation is affected by gradient acoustic noise and various disturbances as well as by other primary tasks. Therefore, we have studied the effects of various disturbances of two different levels of difficulty, that is, weak and strong difficulty levels for primary visual and motor tasks. In the case of visual task with motor and mental disturbances, we found it decreased as motor and mental disturbance difficulty-level increased, compared with the case of without motor and mental disturbances. To the contrary, in the case of motor activity, the total activation of motor cortex with weak and with strong mental disturbance increased as mental disturbance difficulty-levels increased. Therefore, one can conclude that when mental disturbance is added, the visual cortex and motor cortex have an opposite result and when the difficulty-level of the disturbance is increased, the primary tasks are affected more significantly. Although the current observation is preliminary and requires more careful experimental study, it appears that various disturbance effects on brain functions (such as motor and visual cortical responses) produce significant differences in data observations.

Keywords: fMRI, motor and mental disturbances effects on fMRI, fMRI on motor and visual tasks

Introduction

Functional magnetic resonance imaging (fMRI) of the brain, using a variety of acquisition techniques, has been successfully applied to the study of neuroscience (Bandettini et al., 1992; Brummett et al., 1988; Buonocore et al., 1996; Cho et al., 1995, 1996, 1997, 1998; Hinke et al., 1993; Hurwitz et al., 1989; Kennedy et al., 1992; Kim et al., 1993; Kwong et al., 1992; Quirk et al., 1989; Turner et al., 1993). Detection of task-related signal changes in fMRI studies is affected by the presence of gradient noise (Bandettini et al., 1997; Cho et al., 1997, 1998; Shah et al., 1997). The effects of gradient acoustic noise to visual and motor tasks were analyzed by the authors (Cho et al., 1998). The results showed that the effects of acoustic noise on motor and visual responses are opposite. That is, for motor task, there is an increased total motor activation, whereas for visual task, the corresponding (visual) cortical activity is diminished substantially when the subject is exposed to a loud acoustic sound (disturbance).

Task-related activation may also be affected by various disturbance effects such as movement, imagination and mental function as well as by gradient acoustic noise. These disturbances have an influence on the major tasks, and the effects of the disturbances are different according to the major tasks. In this paper we have also studied the effects of the degree of disturbances on our primary task, in this case a primary visual task or motor task based on the difficulty of a secondary disturbance.

We have studied the effects of various disturbances, that is, motor and mental function disturbances. The possible effects of various disturbances for research subjects are many and may include the exhaustion of brain cognitive functions, which may reduce the sensitivity of the response during brain activation. Some of the signal fluctuation in the fMRI is believed to have originated from the unwanted stimulation of motor and mental function pathways in the brain. Therefore, it was felt that the systematic study of various disturbance effects on fMRI would be of interest for future endeavours in the field of fMRI. We report the results of preliminary tests on the effects of various disturbances by changing the difficulty level in fMRI for various cortical responses due to motor and mental disturbances (secondary tasks).

Methods

Experiments were carried out using multi-slice gradient-echo EPI on a standard clinical GE 1.5 T Signa MRI system. Healthy human volunteers (n=5) were studied for both visual and motor tasks under various disturbances. Each volunteer was positioned and secured in a standard head coil position to avoid misregistration.
artifacts. For each fMRI experiment, a spin-echo T1-weighted image was obtained to refer to the anatomical image of the whole brain. For the experimental study, a repetition time of 3 sec, an echo time of 60 msec, a flip angle of 90°, a field of view (FOV) of 260 mm, a slice thickness of 5 mm, and a matrix size of 128 × 128 were used. Whole brain images were obtained within one repetition time, and 50 sequential time series images per slice were obtained for the primary visual and motor experiments, respectively.

To measure the disturbance effects according to varying degrees of task difficulty in secondary stimuli, three sets of experiments were performed for a primary visual task as shown in Fig. 1(a). The primary visual task alone

![Diagram](image1.png)

Fig. 1 Detailed paradigm of the experiments. (a) visual task with and without motor or mental disturbances. (b) Finger tapping task with and without mental disturbances.
was then designated as a case without (V/O) disturbance. For the primary visual task a standard 8-Hz checker-board was used. Then, the second case followed with weak disturbances by adding on an artificial disturbance, such as thumb-motion (V/T-W) or exercising a single multiplication per second (V/M-W). Next, the third case followed with strong disturbances such as programmed finger tapping (V/F-S) or exercising triple multiplications per second (V/M-S). A simple secondary task operation, such as bending and straightening of the thumb, was defined as thumb-motion and was considered as a weak disturbance, while programmed finger tapping was considered a strong disturbance. Both tasks were self-paced (around 3 Hz). Differences in brain activity were then measured between weak and strong disturbances. In each experiment, data was collected which consisted of three sets: the first set without disturbance (V/O), and the second and third sets with weak (V/T-W or V/M-W) and strong (V/F-S or V/M-S) disturbances, respectively.

Next, for the primary motor task studies, two-handed finger tapping was performed by right-handed volunteers as a primary task, and mental disturbance, as a secondary task operation, was added in the same way as mentioned before and shown in Fig. 1(b). Finger tapping was self-paced (around 3 Hz) and consisted of sequential thumb-to-digit oppositions.

Images numbered 1 to 10 were obtained at a resting state (OFF), while images numbered 11 to 20 were obtained with stimulation (ON). This stimulation paradigm was then repeated up to image data 50 for visual task experiments as shown in Fig. 1(a). Images numbered 1 to 10 and 41 to 50 were obtained at a resting state (OFF), while images 11 to 40 were obtained with stimulation (ON) for finger tapping task experiments as shown in Fig. 1(b).

For the primary visual task experiments a standard 8-Hz checker-board was used, while for the primary motor task experiments, two-handed finger tapping was used. Time-course signal processing was carried out using a correlation coefficient (cc) method for each pixel (Bandettini et al., 1993). A box-car waveform was used as the reference waveform (Bandettini et al., 1993). The value of "cc" is varied between -1 and +1. A threshold value (TH) was set between 0 and +1 and each pixel was then selected and assumed activated if cc was larger than TH, i.e., cc ≥ TH. These activated pixels were then superimposed on the anatomical images, and time course data were obtained by calculating the total activation, A_T, which was defined as A_T=number of activated pixels × average pixel intensity (Cho et al., 1998). The TH value for most of the study was set to 0.4 or 0.5.

**Results**

Although the five volunteers showed differences in the number of activated pixels and the amount of average pixel intensity for each of them, all the subjects consistently demonstrated the same trends in activation for both motor and visual tasks when they were exposed to disturbances.

**Primary visual task**

The summary of the averaged total activation for the five volunteers is given in Fig. 2 for motor and mental disturbances. One of the activation maps and the total-activation time-course data of primary visual tasks under the two levels of motor disturbances (thumb motion for weak disturbance and finger tapping for strong disturbance) are plotted in Figs. 3 and 4, respectively. In Fig. 3, in the cases of the visual task with weak (V/T-W)
and with strong (V/F-S) motor disturbances, we found decreased activities of about 40% and 60%, respectively, compared with the case without (V/O) motor disturbance. In Figs. 5 and 6, in the case of the visual task with weak (V/M-W) and strong (V/M-S) mental disturbances, we also found decreased activities of about 20% and 35%, respectively, compared with the case without (V/O) mental disturbance. A simple observation of the activated areas shown in Fig. 3 and 5 clearly demonstrates that the areas of activation are reduced with a stronger disturbance compared with those of a weak disturbance.

**Primary motor task**

Similar to the case of visual stimulation, the summary of the averaged total activation for the five volunteers is given in Fig. 7. One of the activation maps and the total activation time course data of motor cortex by finger tapping under the two levels of mental operation disturbances (exercising a single multiplication per second and exercising triple multiplications per second) are shown in Figs. 8 and 9, respectively. In Fig. 8, in the case of the primary finger tapping task with weak (F/M-W) and with strong (F/M-S) mental disturbances, we found increased

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**Fig. 3** Responses of visual task for: without (V/O), with weak (V/T-W) and with strong (V/F-S) motor disturbances, respectively.

**Fig. 4** Total activation time-course data of visual task under two levels of motor disturbances.
Fig. 5 Responses of visual task for: without (V/O), with weak (V/M-W) and with strong (V/M-S) mental operation disturbances, respectively.

Fig. 6 Total activation time-course data of visual task under two levels of mental disturbances.

activities of about 20% and 40%, respectively, compared with the case without (F/O) mental disturbance. The time-course data shown in Figs. 6 and 9 clearly suggest that differences exist between primary visual and motor tasks when mental disturbance is involved; moreover, the visual and motor responses have opposite cortical responses if subjects are exposed to mental operation disturbance.

Discussion

Various disturbance effects on brain functions (such as the motor and visual cortical responses) produce significant differences in data observations. Our study strongly suggests that differences exist between primary visual and motor tasks when mental operation disturbance is involved, and depending on the degree of disturbances or task difficulties, such as motor and calculation tasks, brain functions produce significantly different data. Visual response decreased as the level of difficulty of motor and mental disturbance was increased. To the contrary, motor response increased as the level of difficulty of mental disturbance was increased. The effects of the motor and mental disturbance to the visual and motor tasks were
found to be the same as the previous results, that is, the acoustic noise (disturbance) effect causes a decrease in cortical response for a visual task and an increase in cortical response for a motor task (Cho et al., 1998). Moreover, motor and visual responses have opposite cortical responses if subjects are exposed to mental
operation disturbances.

A possible explanation of the above-described two-characteristic differences may be that the primary motor task is self-motivated action while primary visual is an externally driven activity. The latter, probably due to the fact that the externally driven activity may require more concentration under disturbance conditions, therefore, could have caused more rapid exhaustion of brain function (Cho et al., 1998). Since the primary motor task is self-motivated action, it is necessary to pay more attention to maintain the same cognitive functions under disturbances, which may increase the sensitivity of the response during brain activation.

In conclusion, we have observed new results of various disturbance effects on brain functional MRI, in particular, the results of motor and visual responses.

References


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